COMPRESSIVE UNDERWATER VIDEO CAMERA (CUVC)

Frank M. Caimi
Department of Electrical and Computer Engineering
Harbor Branch Oceanographic Institute
5600 US I North
Ft. Pierce, FL 34946
phone: (561) 465-2400 x 256 fax: (561) 465-2446 email: caimi@hboi.edu

Gerhard X. Ritter & Mark Schmalz
Department of Computer and Information Sciences
University of Florida, Building CSE-E301
Gainesville, FL 32611
phone: (352) 392-1200 fax: (352) 292-1220 email: ritter@cis.ufl.edu

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LONG-TERM GOALS

Develop efficient real-time and near real-time compression algorithms having large compression ratios (CR) needed for acoustic transmission of underwater image/video/sonar data. Requirements for transmission of high bandwidth data acoustically necessitate compression ratios exceeding those currently achievable with standard methods. In particular, algorithms are required that are tailored to compression of data specific to underwater sensors. Production of efficient, low-error compression schemes suited for both Human-in-the-Loop (HIL) and Automated Target Recognition (ATR) schemes are long term goals.

OBJECTIVES

Objectives of this study and development are to investigate the suitability of standard tranform-based data compresssion techniques such as JPEG, MPEG, Wavelet, EPIC, SPIHT, etc. for compression of underwater image data at variable compression ratios. In addition, modification of existing transform-based compression methods will be devised to minimize errors in reconstruction that are particularly objectionable for HIL applications. It is also intended that an optimally performing set of methods will be selected and used to compress real image data obtained at sea from an an operating autonomous underwater vehicle (AUV).

APPROACH

The approach adopted produces comparison of existing data compression methods using real data sets obtained from existing underwater sensors. Using the derived characteristics of the underwater sensors, methods will be investigated for data compression that tend to minimize characteristic error functions. Errors in reconstructed visual imagery may include edge straightness, block artifact production, resolution degradation, contrast reduction, and other information loss or noise production mechanisms. The technical approach being used for this work can be summarized as follows:

1. Develop database of underwater imagery to support design of image compression transforms.
2. Develop high-compression encoding transform(s) for transmitting multispectral image data

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across noise influenced, low-bandwidth acoustic uplink.
3. Test transforms on database imagery and test imagery gathered in the field. Select two best-performance compression transforms for DSP implementation.
4. Implement and test compression transforms selected in Task 3 using Digital Signal Processor technology and various embedded High-Performance Computing Systems (HPCS), such as Lockheed-Martin's PAL processor (385 MOPs [8-bit] SIMD parallel processor with VME form factor) and Analog Devices “SHARC” family of processors.
5. Conduct tank and field tests of best-performance algorithm onboard AUV or other underwater vehicle.

WORK COMPLETED

Preliminary testing of JPEG, EPIC, and VPIC compressive schemes has been completed. Measures of performance have been developed and inital results have been compiled for an ONR provided data set.

Based upon characteristics observed in images from a 6-band multispectral ISIT camera, a new scheme for image data compression has been developed. The algorithm designated by the acryonym BLAST (for Blurr, Local Average, Sharpen, and Threshold) compares favorably with the other methods tested, providing the highest compression ratio and least mean square error (MSE).

Hardware has been selected and procured for initial implementation of the BLAST algorithm. The system in development uses 4 Analog Devices SHARC processors and operates in conjunction with an IBM comaptible host computer and PCI bus. Initial coding of the BLAST algorithm has been accomplished and code is being debugged. Data will be stored locally, processed (compressed), and streamed to a serial output.

Hardware implementation of a Wavelet-based compression scheme has been demonstrated and is intended as a backup hardware implementation for AUV trails.

RESULTS

Comparative results for the preliminary database trials are best seen using Figure 1. MSE between the original images and the compressed data are plotted as a function of compression ratio for each of the compression algorithms tested. It can be seen that the BLAST algorithm and its derivitives BLAST-II and BLAST-III, which use elliptical encoding blocks (referred to as EBLAST), provide the highest compression ratio at a fixed MSE.

From the results shown in Figure 2, it can be seen that EBLAST provides acceptable visual image quality at CR=240. This is the highest for the algorithms tested to date. BLAST is additionally advantageous in that it is a transform based method that operates on only local neighborhoods in the image, thereby reducing computational complexity.

For comparison to standard images used in the litereature, the “Lena” image was compressed using these techniques, as shown in Figure 3.

Although the results in the previous figures appear impressive, quantitative measurement of performance is necessary for accurate assessment of the relative advantages of each algorithmic method. Derivation of several quantative measures has begun and initial results have been published. MSE, blocking effect, edge integrity, and memory requirements are plotted for VPIC, BLAST, and EPIC in Figure 4 (a-d).

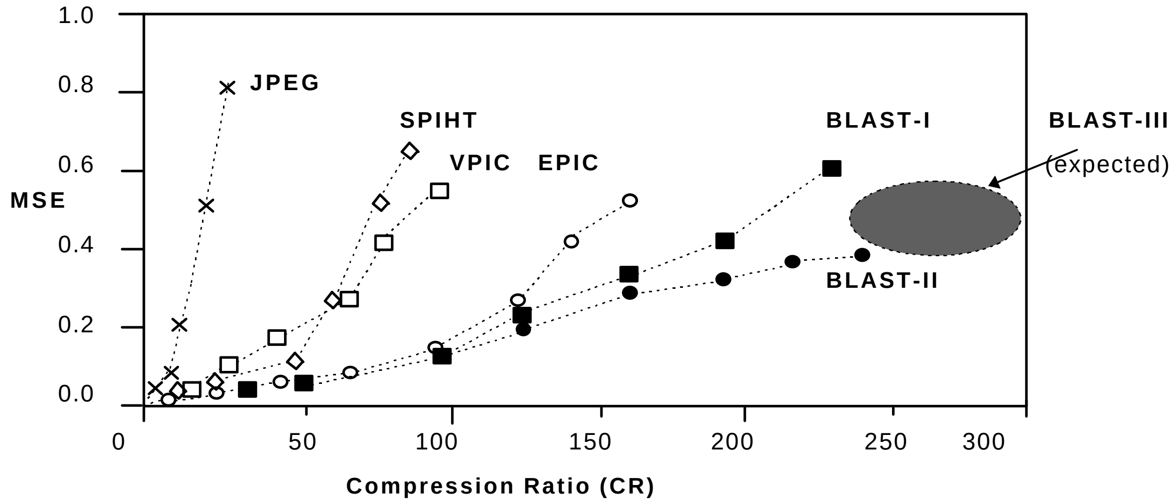
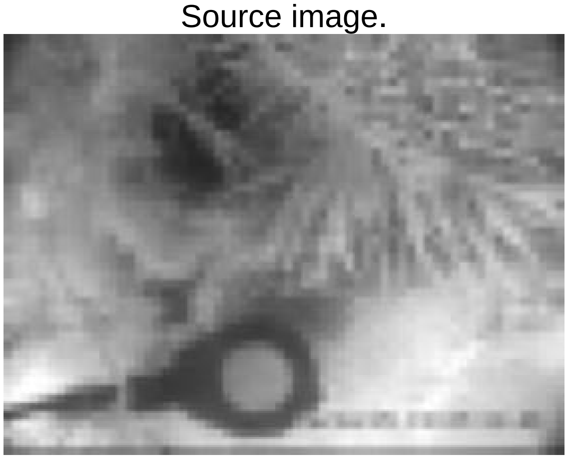


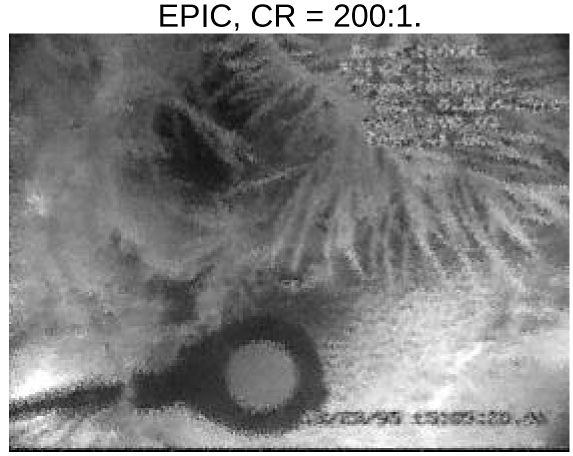
Figure 1. MSE of various image compression algorithms versus compression ratio CR.

Source image.

EPIC, CR = 200:1.



BLAST, CR = 200:1.



EBLAST, CR = 240:1.

Figure 2. Comparison of EBLAST, BLAST, and EPIC algorithms at compression ratios of 200:1 and 240:1 for a typical underwater scene.

Source image. EPIC, CR = 200:1.

BLAST, CR = 200:1. EBLAST, CR = 240:1.

Figure 3. Comparison of EBLAST, BLAST, and EPIC algorithms at compression ratios of 200:1 and 240:1 for the standard "Lena" image.

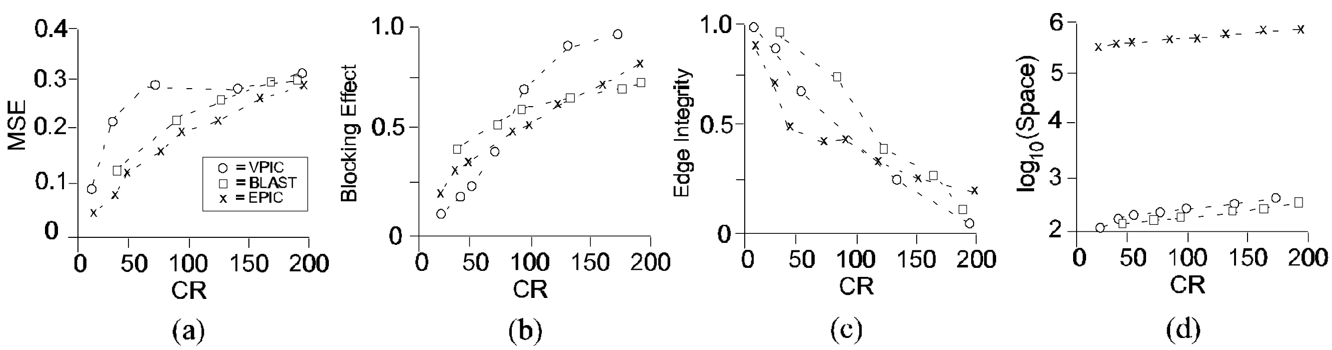


Figure 4. Compression transform performance measures versus compression ratio.

Although EPIC provides visually attractive image quality, image reconstruction errors tend to cluster in regions of high detail, which is problematic for ATR applications. EPIC also requires a large memory model, which can obviate many DSP and massively parallel implementations. In contrast, BLAST and VQ require small memory models and are amenable to parallel execution on SIMD or SMP processors. Our current research indicates that at compression ratios exceeding 150:1, BLAST provides acceptable visual image quality which is comparable to results obtained with EPIC. We plan to test a proprietary VQ algorithm shortly, which is purported to yield results similar to BLAST, but at reduced computational cost.

IMPACT/APPLICATIONS

The CUVC project has direct, immediate utility in three important applications areas: (1) underwater image and data transmission, (2) image transmission over low-bandwidth secure channels, and (3) commercial video telephony. Since our goal is to produce a high- compression, high-quality image transform that has very low computational cost, we foresee significant technology transfer to applications that require high image compression but accommodate only small on-board processors. We are investigating the applicability of our techniques to video telephony, which is an important commercial application. Potential utility also exists for medical image processing (e.g., teleradiology), where large data sets (e.g., 6-10MB per image) must be transmitted efficiently across commercial telephone networks.

TRANSITIONS

The work reported here and its application is related to that being performed elsewhere. Frontier Technology, Inc. of Dayton, Ohio is pursuing aerospace and commercial applications of a proprietary VQ algorithm they have developed. We have entered into a joint program sponsored by Army BMDO to compare performance of these algorithms against Frontier's rapid codebook search method (TNE) using the undersea image database we are developing. If Frontier's VQ method is proven advantageous for undersea image classes and applications, hardware implementation may be attempted using the PAL or SHARC processor hardware being developed in this and other programs with UF and Lockheed.

RELATED PROJECTS

The list below summarizes related work ongoing at other organizations.

1. Frontier Technology, Inc., Dayton, Ohio: Developing Tabular Nearest-neighbor Encoding (TNE) algorithm for use in VQ-based image compression. HBOI and UF have been included in a recent program award from Army BMDO.
2. Naval Coastal Systems Station (NCSS), Panama City, Florida: Developing image compression techniques to be used in mine reconaissance imaging.
3. WHOI, Woods Hole, Massachusettes: Investigating EPIC algorithm for image data compression and demonstrated acoustic link under DARPA sponsorship.
4. Florida Atlantic University (FAU), Boca Raton, Florida: Developing AUV-based acoustic modem which will be used in the demonstration phase of the CUVC project.

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